NATIONAL ACTION PLAN ON BREAST CANCER
Etiology Working Group
Workshop on Electromagnetic Fields, Light-At-Night, and Human Breast Cancer
November 18 and 19, 1997

Workshop Summary

BACKGROUND

The 1½-day Workshop on Electromagnetic Fields, Light-At-Night, and Human Breast Cancer was held on November 18 and 19 at the Loews L'Enfant Plaza Hotel in Washington, DC. The workshop was sponsored by the National Action Plan on Breast Cancer (NAPBC), a public/ private partnership formed to stimulate rapid progress in eradicating breast cancer. The workshop was co-chaired by Robert P. Liburdy from the Lawrence Berkeley National Laboratory and Richard Stevens from the Pacific Northwest National Laboratory.

The goal of the Breast Cancer Etiology Working Group, one of the six working groups that compose the NAPBC, is to expand the scope of biomedical, epidemiological, and behavioral research activities related to the etiology of breast cancer. To that end, the Etiology Working Group established subgroups, one of which focuses on radiation and electromagnetic fields (EMF) and light-at-night (LAN).

The Radiation and Electromagnetic Fields Subgroup organized this workshop to bring together scientists, advocates, and other interested parties to discuss research on the effects of EMF and LAN on breast cancer and, based on what is known and/or suspected about their effects, make recommendations about the appropriate national response. The workshop included nearly 20 presentations on light and EMF in the environment; cellular, animal, and epidemiological studies on the potential effects of EMF and LAN on biology and the initiation and promotion of breast cancer; and the consumer's perspective on appropriate responses to research findings. The meeting also included two question-and-answer sessions and a concluding roundtable discussion in which participants collaborated on developing recommendations for future research and action.

WELCOME
Frances M. Visco

Ms. Visco, Co-Chair of the NAPBC, President of the National Breast Cancer Coalition (NBCC), and a breast cancer survivor, welcomed the meeting participants and provided them with the history of the NAPBC and the goal of this workshop. In addition, she gave an example of how the recommendations developed in this workshop would be used. The recommendations, which identify priority research areas and understudied issues, will form the basis for a national funding

strategy. The NAPBC will communicate these research needs to funding sources such as the National Cancer Institute (NCI), the U.S. Department of Defense (DoD) Breast Cancer Research Program, and private institutes to ensure that the most appropriate research gets financial support and that there is little duplication of effort. She closed by welcoming speakers and participants and thanking them for attending.

INTRODUCTION
Robert P. Liburdy

Dr. Liburdy underscored the importance of dialogue between scientists and advocates. He, Dr. Stevens, and Barbara Balaban organized this workshop to provide a forum for the collaboration of breast cancer advocates and distinguished international researchers.

OVERVIEW OF THE MELATONIN HYPOTHESIS
Richard Stevens

Dr. Stevens provided an overview of the premise underlying the research presented at this workshop: the melatonin hypothesis. Breast cancer is a disease of modern life. Although breast cancer incidence and mortality are increasing worldwide, the risk is five to seven times higher in industrialized nations than in nonindustrialized ones. The risk clearly increases as nations become more industrialized, but the reason is unknown. Research has attempted to explain the international differences in risk, but race, reproductive factors, diet (including fat and alcohol intake), and family history have explained only a portion of this variation.

Research has identified some strong risk factors, including age, country of birth, and having both a mother and sister with breast cancer; some moderate risks factors, including personal history, having either a mother or sister with breast cancer, biopsy-confirmed proliferative disease associated with increased risk, and radiation to the chest at a moderate to high dose; and many weak or potential risk factors. These factors have not explained why risk is higher in some countries, nor have they explained all U.S. breast cancer cases. A 1995 study (Madigan et al.) indicated that only 41 percent of U.S. cases can be explained by known risk factors for which data were available.

In searching for potential environmental factors that could explain the remaining cases and account for international differences, Dr. Stevens developed the melatonin hypothesis. Electric power, a hallmark of industrialized life, produces light-at-night (electric lighting) and a range of non-ionizing electric and magnetic fields, both of which may relate to breast cancer. According to the hypothesis, both LAN and low-level EMF may lower melatonin—a monoamine hormone produced by the pineal gland—which, in turn, may increase breast cancer risk. Melatonin has a strong daily rhythm that peaks at night and decreases during the day. It has been associated with mood and depression and reproductive physiology, and there is some evidence that it may fight breast cancer.

Three components of the melatonin hypothesis are:

1. The effects of light-at-night on melatonin: It is clear from research and from the use of light therapy for seasonal affective disorders that light suppresses melatonin.

2. The effects of electromagnetic fields on melatonin: It is less clear that EMF suppresses melatonin. The results from studies at six or seven laboratories indicate that EMF can suppress melatonin in animals under some circumstances. Due to insufficient research, it is unclear whether EMF has any effect on melatonin in humans.

3. The effects of melatonin on breast cancer: A study that appeared in *Cancer Research* (Tamarkin et al., 1981) suggested that melatonin could have a dramatic protective effect against cancer. All the rats in the study were given a carcinogen (7,12-dimethylbenz[a]anthracene, or DMBA). In contrast to the control group, the rats who additionally were given melatonin had no tumors. Also, the oncostatic properties of melatonin have been demonstrated *in vitro*; melatonin can slow the growth of certain types of cancer cells.

Researchers also speculate about melatonin's mechanism—*how* it affects the development of breast cancer. One hypothesis stipulates that decreases in melatonin lead to an increase in estrogen and prolactin, which increases cell turnover and therefore increases the risk of a malignant transformation occurring. According to another hypothesis, melatonin does not prohibit initiation of cancer cells but rather their growth and spread. The mechanism is important to the design of epidemiologic research because it may affect the length of time prior to diagnosis that exposure has to be examined (e.g., 2 years or 20 years prior to diagnosis). Dr. Stevens concluded by giving an overview of the occupational, residential, and laboratory research that would be discussed by the presenters.

ADVOCATE PERSPECTIVES
Barbara J. Balaban

Ms. Balaban opened by thanking the workshop planning committee and reiterating the purpose of the workshop: to develop reasonable approaches for curtailing the effects of EMF on breast cancer. She disagreed with the 1995 Madigan et al. study referred to by Dr. Stevens, because it used high income as a risk factor to account for 19 percent of U.S. cases. She also underscored the importance of involving advocates in the planning and implementation of research efforts.

Current research, she commented, indicates that EMF is not a direct cause of breast cancer, but it may hasten the growth of cancer cells. Although researchers will continue to search for more definitive answers, the available evidence is strong enough to support prudent, relatively inexpensive avoidance measures. People should examine the EMF in their homes, workplaces,

and environments, and they should take simple measures to abate their everyday exposure to EMF. She asked that participants keep these questions in mind throughout the workshop:

- What are some steps to reduce exposure?
- What should consumers know about minimizing their exposure to EMF from appliances and computers? What questions should they ask when buying a home?
- What changes should appliance manufacturers implement?
- What should homebuilders know about EMF?

STANDARDS OF EVIDENCE NECESSARY TO DEVELOP POLICY
Cindy Sage

Ms. Sage described the debate over enacting prudent avoidance measures, specifically, on whether there is sufficient scientific evidence on EMF to develop policy. Scientists, policymakers, public health experts, litigators, consumers, and others frequently disagree about when to change policy because each group has a different "action threshold," the level of scientific certainty necessary to take action. Understanding others' perspectives, however, may help these groups come to consensus about an appropriate range of action.

Scientists set their action threshold at causal evidence. They generally do not want to take action based on extrapolation of preliminary, inconclusive studies and do not want research to be sidetracked by those who act prematurely. Advocates, on the other hand, believe the required level of evidence falls below scientific certainty, and they have little patience for scientific caution. They want to educate women about potential risks and how to avoid them so women can make educated decisions about their own exposure.

Ms. Sage then described the standards of evidence adopted by three interest groups in the EMF debate:

- Science requires 95 to 99 percent certainty and the fulfillment of several criteria, including cellular, animal, and human studies; replication; and scientific consensus (including industry scientists).
- Law requires 51 to 53 percent certainty, or a preponderance of evidence.
- National environmental regulations require 10 to 30 percent certainty, or the potential for impact.

Although the opinions of workshop participants may reflect the diversity of these approaches, if advocates and scientists consider each other's perspectives, they should be able to propose a mutually acceptable range of action to reduce the potential harm of EMF.

EMF AND BREAST CANCER CELL GROWTH
Robert P. Liburdy

Dr. Liburdy began his presentation by providing a context for his research. To gain the proper perspective on any potential health problem, science requires laboratory studies at the cellular and animal level and epidemiological studies. Dr. Liburdy's work focuses on cells.

Research has demonstrated that melatonin inhibits the growth of MCF-7 cells, the human breast cancer cells traditionally used in breast cancer research (Hill and Blask, 1988; Cos and Blask, 1990; Cos et al., 1991). Tamoxifen, a drug used in the clinical management of breast cancer, has the same protective effect. Dr. Liburdy examined whether EMF would interrupt the normal function of melatonin and tamoxifen, thereby increasing cell proliferation and the risk of breast cancer (Harland and Liburdy, 1997; Löscher and Liburdy, in press). This process relates to the progression of disease.

MCF-7 cultures containing melatonin were placed in a cell culture incubator. In a 2-milligauss (mG), 60-hertz (Hz) field, melatonin inhibited cell growth, but in a 12-mG, 60-Hz field, it did not. Simultaneous experiments using 2- , 6- , 10- , 12- , 20- , and 1000-mG fields yielded a dose response showing increasing cell growth with increasing levels of EMF up to 12 mG, at which point the response levels off. These findings have been replicated independently in two laboratories.

When he extended the MCF-7 cell studies to tamoxifen, Dr. Liburdy found again that growth inhibition was blocked with a 12-mG field (Liburdy et al., in press[a]). He replicated this finding later using tamoxifen and a different human breast cancer cell line, T-47D, which is estrogen receptor (ER) positive (Liburdy et al., in press[b]).

The relevance of this data is underscored by several factors: The EMF levels used in Dr. Liburdy's research occur in homes and workplaces, the melatonin levels used relate directly to physiological levels, and the tamoxifen levels used relate to current pharmacological levels. There are dose-response data for melatonin and tamoxifen, two laboratories independently have replicated the melatonin findings, and the same tamoxifen results were found in two breast cancer cell lines. In addition, these findings relate to the melatonin hypothesis, which is biologically plausible.
The question remains about these findings' relevance to animals and humans. If the results do translate to humans, women exposed to moderate environmental EMF may require higher doses of tamoxifen than those currently prescribed if the drug is to have its intended oncostatic effect. In addition, research must study the involvement of other potential factors, including the estrogen receptor and other natural growth hormones.

EMF EFFECTS ON MELATONIN IN HUMANS
Charles Graham

Dr. Graham's presentation centered on what is known about EMF's effect on melatonin in humans. Melatonin, which is produced in the pineal gland, suppresses cancer cell growth, modulates immune function, regulates reproduction, and controls circadian rhythm. What is known about melatonin from hundreds of primarily cellular and animal studies, however, may not translate to humans; the location of the pineal gland and the way light suppresses melatonin are different in humans than in animals. In addition to these differences between animals and humans, humans have vast individual differences in their nighttime peak melatonin levels and patterns of melatonin release.

Dr. Graham also explained that findings from human laboratory research on EMF and melatonin contradict those from research in real-world settings. Five of Dr. Graham's own laboratory-based, double-blind studies (Graham et al., 1996a, 1996b, 1996c, 1997) and similar studies in France (Selmaoui et al., 1996a, 1996b, 1997) showed no overall effect of overnight exposure to EMF on levels of melatonin. Real-world research on garment, utility, railway, and video display terminal (VDT) workers, however, indicated suppressed levels of melatonin (Kumlin et al., 1997; Burch et al., in press; Pfluger and Minder, 1996; Arnetz and Berg, 1996). The different results, he explained, may be due to characteristics of the laboratory setting that differ from the real world: laboratory research evaluates short-term—rather than chronic—exposure; examines a healthier, less vulnerable population; and uses consistent, well characterized EMF. Real-world exposure may be relatively low over time but has infrequent, extremely high exposures that occur in microseconds.

These short-term, high-energy peaks, "high-frequency magnetic field transients," are under examination in the Thousand Homes study. Data indicate that peaks occurring in the home result from utility operations and appliance use in the home and in nearby homes, and they are more frequent in high wire-code homes. Unlike low-level EMF, these fields theoretically have sufficient energy to cross the cell membrane and possibly to alter cells.

Dr. Graham recommended that research examine whether magnetic field transients can cross cell membranes and damage cells. In addition, research should analyze a more vulnerable population, specifically the age group of 40 to 70 years; study melatonin, reproductive hormones, and the immune system; and examine whether individual differences such as high or low melatonin secretion have an effect on risk and therefore can serve as prognostic indicators.

EMF AND BREAST CANCER IN ANIMALS
Wolgang Löscher

Dr. Löscher's animal research focuses on the ability of EMF to promote cancer cell growth and facilitate tumors' progression to malignancies. He began by elaborating on the melatonin hypothesis as described by Dr. Stevens, offering some progressive mechanisms for the effects of EMF: exposure to a 50- to 60-Hz (low-frequency) magnetic field leads to reduced nocturnal melatonin production, followed by increased production of estrogen and prolactin, increased proliferation of breast epithelial stem cells, and finally, increased susceptibility of breast epithelial stem cells to carcinogens. Once a tumor has been formed, its growth is facilitated by the decreased melatonin (which normally has an oncostatic effect). In addition, the decrease in melatonin may result in a suppressed immune system response to tumor formation and development, thereby further increasing the risk of breast cancer formation. The research he then described illustrated the increased incidence of breast cancer and a few of the mechanisms involved (Löscher et al., 1993, 1994; Baum et al., 1995; Mevissen et al., 1995, 1996a, 1996b; Löscher and Mevissen, 1995, 1997).

The first experiment Dr. Löscher discussed tested whether EMF would increase the development and growth of breast cancer. He administered to all study rats four doses of DMBA. Using exposure chambers, he exposed the experimental group to a 50-Hz, 1-gauss (G) magnetic field for 24 hours a day and the control group to only extremely low-level, stray fields. The incidence and size of tumors were measured during the exposure period with palpation and at autopsy. After 5 to 6 weeks, the first tumors were found. At the end of the exposure period (13 weeks), the 1-G EMF had two effects: compared to sham-exposed rats (rats exposed to only stray fields), the percentage of rats with at least one tumor was approximately 50 percent higher in rats exposed to 1-G EMF, and the median size of tumors was at least twice the size in this group.

When the experiment was repeated using a much lower field (10 mG) for the exposure, at a midpoint in the study, the exposed group showed a tendency for increased tumor growth; at the end of the study, however, there was no difference between EMF- and sham-exposed groups. In addition, experiments using a range of exposures between 10 mG and 1 G illustrated a significant linear dose response for tumor incidence above the control group.

At exposure of 300 G, however, there was no further increase in tumor incidence and even a decrease in the incidence above control. This finding suggests that increasing the flux density above a certain point does not increase the risk, and raising the level further may reduce the tumor incidence seen in lower levels. It also may explain the negative results of some studies that exposed the experimental groups to very high EMF levels.
After establishing that EMF may have an effect on breast cancer incidence in rats, Dr. Löscher tested three hypotheses on the mechanisms leading to increased tumor incidence (in all these studies, rats were either exposed to a sham or EMF condition):

- Hypothesis—EMF exposure reduces the level or function of melatonin. After exposure, rats had a significant decrease in melatonin levels (20 to 30 percent decrease), but the decrease was much less than that caused by a very intense light, and in some rats, there

was no decrease in melatonin. Dr. Löscher concluded that the reduction in melatonin alone cannot account for the marked increase in tumor incidence. However, in addition to decreasing levels of melatonin, EMF may impair the function of melatonin.

- Hypothesis—EMF exposure reduces the level or function of melatonin, which causes an increase in cell proliferation in the breast tissue. Compared to sham-exposed rats, rats that were EMF-exposed had higher levels of ornithine decarboxylase (ODC)—an enzyme critical to cell proliferation—in the breast tissue, but not in other tissues.

- Hypothesis—EMF exposure reduces the level or function of melatonin, which inhibits immune system response. When T-lymphocytes (T-cells) are activated by mitogens produced by tumors, they become cytotoxic and proliferate, inhibiting tumor growth. Researchers harvested T-cells from rats who were sham- and EMF-exposed and then placed the T-cells *in vitro* with a mitogen produced by tumors. While the sham-exposed T-cells responded appropriately, the proliferating capacity of exposed T-cells was limited by at least 50 percent.

Overall, Dr. Löscher said, the various effects of magnetic fields may act together to increase the risk of breast cancer formation. He has been able to replicate his findings, and other laboratories currently are attempting to replicate them.

LIGHT AND MELATONIN IN HUMANS
George C. Brainard

Dr. Brainard presented information on the effects of the visible portion of the electromagnetic spectrum on melatonin in animals and humans. He first explained that, when examining the effects of light on the biology of animals or humans, four parameters of light to consider are its brightness or intensity, spectral quality or wavelength, duration, and time of day.

In animals and humans, light enters the eye and stimulates the retina. From the retina, one signal goes to the visual cortex, which enables sight, and another travels along an indirect pathway to the pineal gland, where it regulates melatonin production. Through this indirect pathway, light and dark regulate melatonin in a consistent daily rhythm.

Experiments which different intensities of light are applied to animals' eyes at night yield a dose response: as brightness increases, melatonin production decreases. However, in low light sufficient for the experimenters to see the animals, melatonin was not decreased, suggesting that light intense enough to activate the visual system is not necessarily intense enough to affect biology.

Two studies with humans found similar results. In a landmark 1980 study (Lewy et al.), plasma melatonin was suppressed in healthy humans exposed to bright light in the middle of the night.

However, the same individuals exposed to less bright light—levels of light normally found in the office and home—experienced no suppression of the hormone.

In a more recent experiment, (Brainard et al., 1988), volunteers who gazed into a bright light source in the middle of the night showed as high as 60 to 80 percent suppression of the hormone, while no significant decrease occurred in those exposed to a low-intensity light powerful enough for the experimenters and subjects to see each other and identify the color of the light. Melatonin could be suppressed at a much lower light intensity in this study than in the Lewy et al. study. The discrepancy between these results may be explained by experimental factors and has led to much research on the characteristics of light exposure that induce biological effects, such as pupil dilation and the spatial distribution and temporal pattern of the light source.

Dr. Brainard closed with comments about light, biology, and evolution. Society considers light a means to see but rarely acknowledges its power to induce biological change. Accordingly, those who design lighting traditionally have aimed to stimulate the visual system and maximize energy efficiency, not optimize biology. In the last 100 years, man has become an indoor dweller who uses light-at-night. Perhaps man's environment has changed faster than man has evolved, and this change may be important in the etiology of breast cancer.

BREAST CANCER IN BLIND WOMEN
Robert A. Hahn

Dr. Hahn tested the melatonin hypothesis using previously collected data, a method that avoids the costly and time-consuming efforts of new data collection but is restricted by the limitations of existing data. Because no data were available on breast cancer in women exposed to constant light, Dr. Hahn could not directly test whether uninterrupted light increases the risk of breast cancer. Instead, he reframed the hypothesis: profoundly interrupted light may reduce the risk of breast cancer. He studied the occurrence of breast cancer in women whose exposure to light was interrupted endogenously—in women with profound bilateral blindness (Hahn, 1991).

The study used data from 1979 to 1987 collected by the National Hospital Discharge Survey, which abstracts more than 180,000 records from a sample of U.S. hospitals each year and tracks patient demographics, hospitalization events, and as many as seven discharge diagnoses for each patient. Dr. Hahn assumed that blindness was such a profound condition, it probably would have been recorded regardless of the principle diagnosis and would not have been recorded differentially for cases and controls. He counted all women with any diagnosis of breast cancer (11,769 women) as cases and all with coronary heart disease (71,615) or stroke (21,664) as controls (women with a diagnosis of diabetes were not counted for either group), and he controlled for several potential confounders on which there were available data, such as marital status and age.

Among the cases and controls, there were 268 women with profound bilateral blindness. The risk of blindness among women having breast cancer was 0.60 of the risk of women with coronary heart disease and 0.49 that of women with stroke. In other words, there was a negative association between profound bilateral blindness and breast cancer incidence. There was no association between blindness and breast cancer among women age 65 and older; the rarity of blindness prevented the effect from being studied in women younger than 45. Marital status did not appear to be a confounder.

In related research, Garland and colleagues (1990) tested and upheld a hypothesis that women living in regions with high levels of sunlight exposure are at lower risk for fatal breast cancer than women in regions with lower sunlight exposure. When skin is exposed to natural light, the body produces vitamin D, which is thought to protect against cancer. This hypothesis may appear at first glance to contradict the melatonin hypothesis. Depending on requisite doses of sunlight and uninterrupted darkness, however, women could be protected by both mechanisms.

Although Dr. Hahn's study may not lead to a direct intervention, he concluded, it might indicate a role for sleeping environments in the etiology of breast cancer.

MELATONIN AND BREAST CANCER ETIOLOGY
David E. Blask

Before examining the research on how light may be involved in carcinogenesis, Dr. Blask quickly reviewed some research findings connecting melatonin to breast cancer: women with ER-positive breast cancer compared with age-matched, healthy controls had suppressed nighttime melatonin, whereas women with ER-negative breast cancer had normal nighttime levels (Tamarkin et al., 1982); women with primary breast cancer had a suppressed nocturnal rise in melatonin, whereas women with secondary breast cancer had normal levels (Bartsch et al., 1989); rats that had pinealectomies had a higher incidence of DMBA-induced breast cancer than those with the pineal gland intact (Tamarkin et al., 1981); and growth of tumors induced by another carcinogen, nitroso-N-methylurea (NMU), was stimulated in animals given pinealectomies and later was inhibited with an injection of melatonin (Blask et al., 1991).

Dr. Blask then focused on how light may contribute to carcinogenesis. A link between light and breast cancer in animals was demonstrated by a group of researchers who found that healthy animals exposed to constant light compared to those exposed to an alternating light/dark cycle showed an increase in the expression of estrogen receptors in normal mammary tissue (Seshadri et al., 1992). When given DMBA, the rats in constant light had more tumors than those in alternating light. Perhaps the lack of a melatonin rhythm caused by light made normal breast tissue more susceptible to carcinogens (Shah et al., 1984).

Research by Shah et al. (1984), however, does not support the hypothesis that decreases in melatonin result in the stimulation of estrogen and prolactin. In this study, healthy

pinealectomized animals experienced a decrease in melatonin but no resulting increase in prolactin or estrogen, indicating that the reduction in melatonin alone does not cause the increase in the two other hormones. Exposure to constant light, however, both decreased melatonin and increased prolactin. Although reduced melatonin does not appear to result in increased prolactin or estrogen, it does result in less protection against a number of cellular growth factors, including estrogen and prolactin.

Dr. Blask also examined the connection between light, diet (specifically, in connection with lineolic acid), and cancer. Linoleic acid is an essential poly-unsaturated fatty acid that, like estrogen and prolactin, appears to act as a mitogenic signal. Dr. Blask conducted research on the metabolism of a liver tumor by transplanting it to a specific area in a rat; the tumor was supplied by a single artery and drained by a single vein (Sauer et al., 1997). When the blood to the tumor contained linoleic acid with no melatonin, the tumor absorbed the acid and produced the mitogenic metabolite, 13 hydroxyoctadecadienoic acid (13-HODE). When melatonin was added to the blood, however, linoleic acid uptake and the production of the metabolite markedly decreased. In addition, when the supply of melatonin followed the day/night rhythm, the uptake of linoleic acid and production of 13-HODE responded to the rhythm. Therefore, melatonin blocks the uptake and conversion of linoleic acid to the metabolite, thereby preventing cancer cell division (Blask et al., 1997). A similar result was found in NMU-induced mammary tumors (unpublished results).

Dr. Blask conducted a similar experiment that included light as a factor. He exposed one group of animals to a light/dark cycle, one to constant light, and one to a light/dark cycle in which the dark phase was contaminated with a very low level of light (0.2 lux) (Dauchy et al., 1997). While the first group maintained its melatonin rhythm, the rats in the second and third groups did not experience a rise in melatonin at night. The rats in constant light additionally experienced a loss of circadian rhythms, and therefore fed around the clock and maintained constant fat intake throughout the day. The group exposed to constant light and the group exposed to the light/dark cycle with contaminated dark both had twofold increases in the rate of tumor growth, in linoleic acid uptake, and in mitogenic metabolite production. These results strongly indicate that the uptake of linoleic acid, the production of its metabolite, and the resulting tumor growth are due to the lack of melatonin, linking environmental light and diet.

PANEL DISCUSSION AND QUESTIONS FROM THE AUDIENCE

Light and Melatonin

Over the course of the discussion, several questions about practical concerns were directed to Dr. Brainard. When asked about the advantage of lighting products offering full spectrum light, he answered that *full spectrum* is a marketing term totally undefined by the scientific and engineering community. There are approximately 15 of such products, and, although they are not harmful, they all produce different patterns of wavelengths and do not simulate sunlight.

When asked about different sleeping habits, he explained that getting up in the middle of the night to go to a restroom with a dim nightlight would not affect the normal melatonin rhythm, nor would taking a nap during the day using an eyeshade, unless the nap exceeded ½ to 2 hours. In addition, he recommended (for those not working unusual shifts) taking advantage of the natural stimulation of the sun by sleeping with open window shades. The circadian system responds to the transition from full darkness of night to dawn, which is detected by the eye. People who do not have the option of sleeping with open window shades can consider getting a dawn simulator in their bedroom.

In reference to Dr. Hahn's research with blind women, one participant asked if the circadian system can detect light absorbed through the skin. Current literature indicates that only light received through the eye affects melatonin and the circadian system.

Research Approaches

Several of the participants questioned the experimental conditions and measurements used in the research presented.

First, there was concern about the differences between EMF wave forms in the environment versus those used in the laboratory. While exposures in the environment include short-term peaks and transients, exposures used in research are often well-characterized, sinusoidal waves. Although none of the researchers present had experimented with transients, Dr. Liburdy mentioned his research using saw-toothed VDT wave forms, which are real-world exposures. He also reminded the participants that sinusoidal waves do exist in the real world and may be the dominating wave form in the environment.

Participants similarly questioned how the type of light used in experiments parallels that in the environment. Dr. Brainard answered that, since the refined form of light used in the research could be used in the built environment, the light used in research is not confined to the laboratory. Dr. Kripke stated his opinion that light-at-night does not appear to be a major source of variability of melatonin, and another speaker added that there is constancy to the melatonin rhythm. Even when subjects are exposed to a bright light at melatonin's peak time, following a significant decrease, the level of melatonin returns to normal after 1 to 2 hours. However, melatonin levels rebound better at this time than at other times.

Third, panelists and participants discussed measurements of melatonin. A participant asked the speakers why researchers do not measure daytime suppression of melatonin, since significant EMF exposure occurs during the day. Although the measurement may be useful, especially if taken in the late afternoon and early evening, speakers answered that daytime melatonin levels generally are too low for changes to be detected by the assay.

New Research Topics

Participants identified two areas that seem to be lacking in the research: the anti-oxidant properties of melatonin and the therapeutic use of melatonin. Although melatonin has been shown to have powerful anti-oxidant properties at pharmacological levels, one speaker said, the question remains as to whether physiological levels of melatonin can be an important part of the anti-oxidant defense system. Although the anti-oxidant mechanism may not be melatonin's most important mechanism, researching it is important because it relates to many types of cancer.

Whether to pursue research on the therapeutic use of melatonin raised more controversy. Currently, tamoxifen is prescribed for the postsurgical, clinical management of breast cancer because it inhibits cell growth. Some women would prefer a less invasive therapy and therefore call for a clinical trial to test melatonin—an endogenous substance—alone as a treatment. Two significant obstacles prevent such an experiment: (1) melatonin cannot be patented, so pharmaceutical companies will not pay for clinical trials; and (2) ethically, researchers cannot deny access to treatment with known benefits (i.e., tamoxifen). Researchers may, however, integrate melatonin into a tamoxifen study.

The debate about melatonin's clinical use prompted a discussion about people taking over-the-counter melatonin to slow cancer and to "stay young." The only approved medicinal use of melatonin is as a sleep aid, but it can be purchased without a prescription as a dietary supplement and is unregulated. The amount of melatonin in dietary supplements ranges from none to 10 times the indicated dose, and more melatonin than vitamin C was bought in the United States in the past year in spite of its unknown effects: there are no data about its bioavailability (how much is actually absorbed in the body), long-term toxicity, or side effects. In addition, the preparations may include other unregulated substances.

Reproductive Hormone and Immune System Response to EMF

Panelists asked Dr. Graham to present the results of his research on the effect of EMF on reproductive hormones and the immune system. Testosterone rises in the night normally, but in Dr. Graham's research, EMF lowered testosterone levels in men who naturally secreted low levels of melatonin (Graham et al., 1996b). In women with normal menstrual cycles and stable levels of estradiol, EMF exposure increased their levels of estradiol without affecting their melatonin (Graham et al., 1996a). Lastly, EMF disrupted the pattern of natural killer cells, which normally peak at the beginning of the night and are lower in the morning. EMF intensified the overnight decrease in natural killer cells in men but not in women (Graham et al., 1996b). It is not known whether these physiological effects cause negative health effects over time.

Funding Research

In response to questions about funding cuts, speakers and participants shared dismay over the potential loss of groundwork that researchers have laid. Although only one of the speakers was funded by the U.S. Department of Energy (DOE) Rapid Program, which may lose funding at the end of FY98, other researchers will lose funding from other government sources that are making budget cuts.

Breast cancer advocates suggested that scientists collaborate with the NBCC and local advocacy groups to secure funding. For example, researchers should join advocates from the NBCC when they lobby the U.S. Congress. They can corroborate the advocates' statements with scientific facts, and they can use the advocates' power to garner financial support.

The State of the Science and Appropriate Recommendations

Throughout the discussion session, researchers commented on their level of confidence in the melatonin hypothesis based on research to date. Most agreed that the melatonin hypothesis is speculative; to advise the government to take action now without further research would be to overstate the data. In addition, they felt they should have enough data to provide levels of harm before asking the government to mandate safety measures. Some participants did agree, however, that the evidence is strong enough to prompt them to take prudent avoidance measures in their own homes.

To encourage speakers and advocates to compromise on some immediate recommendations, one participant warned that the International Radiation Protection Association's standard is 1000 mG, in spite of evidence indicating that dangerous exposure may occur at levels as low as 1 to 5 mG.

A speaker added that recommendations should attempt to make the public more aware of the controversy about EMF. Electricity became a part of daily life before research could evaluate its potential effects, and now that the technology is in place, people are reluctant to advocate change. Although closing the utility companies is not the answer, enabling engineers and biologists to collaborate with each other and with advocacy groups will help advance the research and bring the issue into public view. A participant stated that U.S. government agencies are responding to industry pressure by downplaying the potential risk, and only public pressure opposing that of the industry will effect change.

Participants then called for an advisory statement about what is known and believed based on the research, an endorsement of ALARA (as low as reasonably achievable) or prudent avoidance measures, and changes in manufacturing policies.

Extensive discussion addressed the use of gauss meters by consumers who want to test their own homes and workplaces occasionally to characterize their exposure. Although utility companies will measure EMF in a home at the homeowner's request, they will not explain what the measurements mean. Participating advocates agreed that gauss meters should be available in

public libraries and through breast cancer advocacy groups that are trained in their use and can explain the results. Many meters are available on the market, but their quality varies, so consumers should research them before buying one. Participants recommended that a consumer group review and rate gauss meters.

BREAST CANCER AND SOCIETY
Nancy Evans

Ms. Evans' presentation focused on society's past and present response to breast cancer. Breast cancer is not a new disease, but the epidemic is new, and it is a relatively new political issue. Until recently, she said, people could not openly discuss the disease. Now that they can, women want to understand its causes.

The only proven cause of breast cancer is ionizing radiation, which also is used to detect and treat the disease. Women also have been told that their cancer results from faulty genes, unwise reproductive choices, stress, diet, alcohol and too little exercise. However, external causes also should be considered. Today's society lives in a "toxic soup" created by chemicals and wired and wireless technologies. Women want to know how their genes, biologies, and behaviors interact with these environmental factors.

Although finding the specific cause of breast cancer among all these interactions is a daunting task, the overall picture indicates that breast cancer is a symptom of a much larger public health problem. Risks of all types of cancer are increasing, even in children, as are risks of many chronic illnesses.

Current research, although inconclusive, suggests that power lines may be associated with some increased health risks. Countries that provide health care to all their citizens, such as Sweden and Norway, respond to such research with policy changes based on prudent avoidance. In the United States, however, health care is an industry. Research in this area largely has gone unnoticed in the United States because industry scientists and others demand solid proof before taking steps to increase safety.

Society cannot continue to wait for scientific proof. Ms. Evans recommended taking three steps now: (1) via a major public education campaign spearheaded by NCI, the Environmental Protection Agency (EPA), and DOE, expose the health risks of EMF and explain how to measure and mitigate those exposures in homes and workplaces; (2) continue to fund research on occupational exposures and how they can be mitigated; and (3) continue to fund research on the mechanisms by which electromagnetic fields affect our health.

OCCUPATIONAL STUDIES
John S. Reif

Dr. Reif explained the epidemiologic body of evidence relating occupational exposure to EMF and breast cancer in men and women. Occupational studies are useful because they allow efficient data collection on a large group of people and because occupational exposures are higher than those in residential settings.

Three basic methods of characterizing occupational breast cancer risk are:

1. Identifying a group of people with occupations that suggest high exposure and comparing their morbidity and mortality against those of the general population (historical cohort study).

2. Identifying a group of people with cancer and a group without cancer who come from the same population base and comparing the two groups' likelihood of occupational exposure (case-control study).

Examining death certificates (which indicate cause of death and occupation) of a group of people with cancer and a group without cancer and comparing the two groups' likelihood of occupational exposure.

First, Dr. Reif overviewed the research to date on male breast cancer. Although male breast cancer is rare, it is histologically similar to female breast cancer. A study by Matanoski et al. (1991) found that the risk of male breast cancer in U.S. telephone workers was sixfold that of the general population, but the results had a wide confidence interval due to a very small number of cases (two). A Norwegian study using cancer registry and occupational data compared the risk in electric workers to that of the general population and found a twofold risk (Tynes and Andersen, 1990).

Demers et al. (1991) conducted a large study of male breast cancer and occupational exposure. When combining data collected on workers in different jobs involving EMF exposure, Demers et al. found an 80 percent increase in risk over the general population. Another large U.S. study (Loomis, 1992), however, found conflicting results. Loomis examined registered deaths and found that, of the 250 male breast cancer cases, only 4 were occupationally exposed, and no increased risk was found. Differences in exposure may explain the higher risks found in the Demers et al. study, which found that men exposed for a longer period (for over 30 years) and at a younger age (younger than 30 years) had the highest risk.

There were six additional occupational studies on male breast cancer that were discussed briefly (Guénel et al., 1993; Rosenbaum et al., 1994; Thériault et al., 1994; Floderus et al., 1994; Fear et al., 1996; Stenlund and Floderus, 1997). A study of Swedish railway workers found an association with male breast cancer (Floderus et al., 1994); the remainder did not. Overall, the evidence for an association between male breast cancer and occupational exposure to

electromagnetic fields is weak and inconsistent. The major problem in studying this condition is the small number of cases available for analysis.

Dr. Reif turned to a discussion of female breast cancer. Four studies conducted in the United Kingdom, Sweden, and Denmark found no association with work in industries with exposure to electromagnetic fields (Vägerö and Olin, 1983; Vägerö et al., 1985; Guénel et al., 1993; Fear et al., 1996). In the United States, two studies suggested a possible link. The first, by Loomis et al. (1994) found a 38 percent increase in risk of developing breast cancer among women who were occupationally exposed in several types of jobs. Adding 1 more year of data to the same data set and using a different method of classifying exposure, Cantor et al. (1995) could not confirm the results of Loomis et al.

In another U.S. investigation, Coogan et al. (1996) studied occupational exposure among 6,851 cases and controls and adjusted the findings for known risk factors for breast cancer. Women with a potential for high exposure had a 40 percent increase in risk, while women with a potential for medium to low exposures had no increased risk. Premenopausal women were at higher risk than postmenopausal women.

A Norwegian study also suggested a possible link. Tynes et al. (1996) found that female radio and telegraph operators had a 50 percent increase in risk of breast cancer compared to the general population. Women age 45 to 54 were at highest risk. Shift work, exposure to radio frequency fields, and exposure to light-at-night may have played a role in increasing risk for this occupational group.

In conclusion, Dr. Reif said, the findings are inconsistent for female breast cancer, and the studies are weakened by inadequate control for known risk factors. They do, however, suggest clues about potential interactions between EMF and age, menopausal status, light-at-night, and shift work that should be explored further.

SWEDISH EPIDEMIOLOGIC DATA
Maria Feychting

Dr. Feychting presented her study of residential exposure, which tested the hypothesis that EMF generated by high-voltage power lines would increase the incidence of breast cancer (Feychting et al., 1997[1]).

She began her study by identifying the population of people living within Swedish power line corridors (within 300 meters of 220- and 400-kilovolt [kV] power lines) at any time between 1960 and 1985. Within the corridors, only 10 to 15 percent of residents were exposed to high

[1]The full paper will be published in *Epidemiology* in July 1998.

levels of EMF. Using the Swedish cancer registry, researchers found 699 female and 9 male breast cancer cases within the corridor and age-matched them to 699 female and 72 male controls also within the corridor. Using theoretical calculations based on power line configuration, annual average load on the line, and distance to the line, researchers estimated the EMF exposures of the cases and controls for the years immediately preceding either the breast cancer diagnosis or moving from the corridor. In addition to comparing the exposures of cases and controls, researchers evaluated the effect modifications of age and ER status.

For all women, there was no difference in risk between the high and low exposure groups, nor was there a difference in risk between the high and low exposure groups for women age 50 and older. There was, however, a nonsignificant increase in risk associated with high exposure for women below age 50 and for men of all ages. While ER-negative status seemed to have a protective effect, there was a slight significant increase in risk among ER-positive women, but this increase was confined to women younger than 50 years. Dr. Feychting noted several times that the confidence intervals for the results were extremely wide due to the small number of cases.

After describing some of the study's strengths and weaknesses, Dr. Feychting made the following concluding remarks: the study indicates the possibility of increased risk for breast cancer—especially for ER-positive breast cancer—in EMF-exposed younger women and of slight increased risk for EMF-exposed men. Since the number of cases was so small, however, random variation could explain the differences in risk, and more research is required before drawing conclusions.

NEW SEATTLE EPIDEMIOLOGIC DATA
Scott Davis

Dr. Davis described two studies conducted by his research team: (1) a large, epidemiologic study, currently in progress, to test effects of EMF and LAN on the incidence of breast cancer and (2) a nested study testing whether these exposures affect nocturnal melatonin levels in healthy women.

The purpose of the first study is to evaluate whether residential exposure to power-frequency EMF and/or LAN increases the risk of female breast cancer. Researchers identified 800 cases using the Cancer Surveillance System, a population-based registration system in the Seattle area, and then matched them by age and county of residence to 800 randomly selected controls with no history of breast cancer. Three methods were used to collect measures of exposure: in-person, detailed questionnaires; construction of wire codes; and measurements of EMF and LAN in the bedroom. This study will compare the case and control groups' exposures by each of these measures, as well as by all the measures combined, and will be able to account for major known risk factors. All of the data are collected, but, because the analysis is not complete, no results are available at this time.

In a companion study, the same group of investigators examined whether these exposures influence nocturnal melatonin levels in 200 women with no history of breast cancer. Using a

sample of controls from the large epidemiologic study, researchers selected some women from a range of exposures and all the women with the highest exposures. Exposure assessment consisted of an interview, a 72-hour EMF and LAN measurement in the bedroom, a 72-hour personal EMF measurement, a 72-hour personal activity diary, seasonal repetitions of measurements, and the wiring code information previously collected. The melatonin metabolite was measured each night.

Factors significantly associated with lower nocturnal levels of melatonin included increased age; season of the year (longer daylight); alcohol consumption on the night of the measurement; increased body mass index; and use of certain medications, such as beta-blockers, calcium channel blockers, and psychotropics.

After accounting for these factors, researchers analyzed the data and found that increases in EMF in the bedroom were associated with decreases in the melatonin metabolite. The effect was strongest in women taking the above medications, in older people, and during the months with the longest daylight. Factors having no significant effect on nighttime melatonin levels were wire-code configurations, personal exposure measurements, short-term variability in EMF level, light-at-night at and above 10 lux, number of times waking in the night and turning on lights, menopausal status, smoking, height, and electric blanket use.

These findings, said Dr. Davis, may help focus research on people who may be especially susceptible to EMF due to low baseline nocturnal levels of melatonin. The biological significance of melatonin reductions, however, is unknown. Future research should examine the effects of EMF and LAN exposures on human endocrine functions. In addition, he proposed an experimental design in which each female subject could be exposed to low and high levels of EMF and LAN and therefore could serve as her own control.

ONGOING LONG ISLAND EPIDEMIOLOGIC STUDY
M. Cristina Leske

Dr. Leske's case-control study, the Electromagnetic Fields and Breast Cancer on Long Island Study, has not yet been completed. Its purpose is to evaluate the association between EMF exposures and breast cancer among Long Island women. Concern from the community about environmental causes of breast cancer led to a legislative mandate funding several studies collectively called the Long Island Breast Cancer Study Project. Although Dr. Leske's study is not part of the mandate, she explained, her study's subjects are a subset of the larger project. She and her team of researchers will compare about 600 cases and 600 controls who have lived in their current homes for at least 15 years.

The first phase of the research, which has been completed, was a pilot study to compare data collection methods for accuracy and to refine the protocol. The pilot showed that the best predictors of EMF exposure were 24-hour measurements in the bedroom, 24-hour measurements in the most frequently used room other than the bedroom, and the ground current measurement.

These measurements therefore were chosen for the study in addition to three spot measurements and wire coding.

To date, half of the data for the epidemiologic study have been collected. After estimating EMF exposures, researchers will compare those of cases and controls and will take into account the effect of all known risk factors (information that is available from the larger study). The results probably will not be reported before 2000.

Dr. Leske added that an advisory committee of experts provided input for the study, as did a community advisory group that also developed brochures and raised funds for the research project. She suggested that other researchers consider adopting this model.

EMF IN THE ENVIRONMENT
William T. Kaune

Dr. Kaune provided a primer on electric charge, electric current, and magnetic fields. Electric charge, like mass, is a fundamental characteristic of matter. Protons in the nuclei of atoms are positively charged, and electrons, which circle the nuclei of atoms, are negatively charged. In the universe, essentially equal amounts of positive and negative charges exist; in human bodies, there are exactly equal parts. Like charges repel each other, and opposite charges attract each other. These forces between charges hold atoms together.

One of the most important manifestations of electric charge is electric current, which occurs in a conductor when a force is applied and electrons travel from atom to atom. Current allows the transfer of energy from a generator to an appliance. Electric charges produce electric fields, which are measured in volts per meter (V/m). Electric current produces magnetic fields, which are measured in microtesla (μT) or milligauss.

Electric and magnetic fields occur naturally. The earth's mean fields are largely static (about 130 V/m and between 30 and 70 μT), but they fluctuate with weather conditions (such as thunderstorms and lightning), geomagnetic disturbances, and solar magnetic storms.

Since industrialization, however, the levels of electric and magnetic fields to which people are exposed have increased greatly. The largest study of residences in the United States found that 95 percent of homes have magnetic fields higher than 0.1 mG; 50 percent, higher than 0.6 mG, and 5 percent, higher than 2.9 mG. Near power lines, the EMF can be as high as 300 mG. Most residences have electric fields below 10 V/m, and power lines have fields up to 10,000 V/m. Some occupational exposures to these electric and magnetic fields are even higher.

Although environmental fields are higher now than before industrialization, the level of these fields that are inducted into the body and of the fields that exist inside the body for its normal

function are much lower than those found in the environment. Dr. Kaune suggested that more experiments would be necessary to show how these fields affect biology.

PANEL DISCUSSION AND QUESTIONS FROM THE AUDIENCE

Before the discussion began, Eva Norman, a representative from the World Conference on Breast Cancer, spoke briefly about the organization's successful July 1997 conference. The next conference is scheduled for July 1999 in Ottawa, Canada.

Questions on Swedish EMF Exposure

Several participants asked Dr. Feychting about her research and how the exposures in Sweden compare to those in the United States. During this exchange, Dr. Feychting indicated that her study did not collect data on exposure 8 to 20 years prior to diagnosis because few EMF-exposed people lived in the power line corridor for that long. Since breast cancer may be initiated many years before diagnosis, some participants called for an epidemiological study that would include estimates of long-term residential and occupational exposures.

Dr. Feychting also said that Swedish power lines are constructed differently than lines in the United States. In addition, most distribution lines in Sweden are buried, so the majority of exposure comes from transmission lines. The rates of breast cancer in Sweden are high but not as high as U.S. rates.

Related Research Topics

When asked about research on ER status in men, a speaker responded that men with breast cancer are overwhelmingly ER positive. According to one participant, a University of Southern California study found that the biological marker most related to underlying genetic predisposition to breast cancer in women was ER expression. Another participant mentioned a study that found that perhaps eight percent of women are carriers of the ataxia telangiectasia (AT) gene, which increases sensitivity to radiation. Most breast cancer, however, occurs in women who have no known risk factors and test negative for BRCA, a gene associated with increased risk. None of the speakers had studied the BRCA gene.

Another participant asked if any researchers had examined the chemically and environmentally sensitive population. Anecdotal reports have discussed the condition, speakers said, but researchers only are beginning to study it.

Weaknesses in Research Design

Several limitations of research designs were discussed throughout the session. First, death certificates, when used for data collection, introduce weaknesses into a study because they

sometimes misclassify occupation and causes of death. Death certificates do not always list all the contributing causes of death or all the occupations during an individual's lifetime.

Participants also discussed problems with measuring melatonin. Although the most accurate measurements of melatonin are taken in the pineal gland and plasma, melatonin is most frequently measured indirectly through its metabolite in saliva or urine. Although these measures accurately estimate total melatonin production, they cannot reflect the moment-to-moment changes in production resulting from environmental stimuli. Researchers, therefore, must use caution when evaluating fluctuations in the metabolite.

When a participant asked why personal exposure measurements were not included in the Seattle epidemiologic study described by Dr. Davis, a debate ensued about a weakness of case-control studies: it is difficult to estimate cases' prediagnosis exposures based on current exposures. The process of diagnosis, treatment, and recovery may influence the woman's environment, making her exposure very different from exposure before diagnosis. Since case-control studies are nonexperimental and therefore have inherent weaknesses, they must be as methodologically sound as possible to produce credible results. Researchers can characterize only a part of previous exposure through current bedroom measurements, which are a reasonable estimate of in-house exposure.

Participants and researchers then talked about the reason for conducting so many case-control studies. Compared to prospective studies, case-controls require much less time and money and frequently result in the same findings as more expensive experimental studies. If breast cancer takes 8 to 20 years to develop, however, a case-control study that estimates exposure for the year prior to diagnosis would not be as useful as a long-term prospective study.

The following proposal emanated from this discussion: Researchers could add a prospective study on EMF, melatonin, and breast cancer to an existing research project by measuring the healthy controls' melatonin and EMF exposure. Although the suggestion was well received, this design is problematic because the incidence of breast cancer in the controls would have to be high for the study to have strong statistical power.

Parallels to Tobacco Research

Participants debated whether there was a parallel between the results of EMF/breast cancer research and tobacco/lung cancer research. Some were uncomfortable with a parallel being made because the tobacco research indicates a higher than 20-fold risk of lung cancer from smoking, whereas epidemiological studies of EMF have been inconclusive and at most have suggested a 2-fold increase in risk. A few people upheld the parallel, explaining that the increased risk of developing breast cancer due to EMF is “diluted” because there is no unexposed population. In addition, the risk found in EMF research may be underestimated as a result of exposure misclassification due to measurement techniques that are not as exact as those used in tobacco

research. The higher than 20-fold risk found in the tobacco research comes from studies comparing nonsmokers to heavy smokers. When comparing moderate smokers to heavy smokers, however (which is similar to comparing moderate EMF exposure to high exposure), the increased risk is only two- to three-fold.

ONGOING LOS ANGELES EPIDEMIOLOGIC STUDY
Stephanie J. London/William T. Kaune

Because Dr. London, the Principal Investigator of the Los Angeles study, could not attend the meeting as planned, Dr. Kaune presented Dr. London's slides describing her study in progress.

The primary aim of the Los Angeles epidemiologic study is to investigate whether female breast cancer is related to (1) exposure to 60-Hz magnetic fields and/or (2) specific combinations of an alternating current (AC) and a direct current (DC) field. A secondary aim is to learn if the biological responses to EMF are due to EMF's harmonic component.

This study is examining a subgroup of women age 45 to 74 selected from a larger study. Exposure assessment for this study consists of a questionnaire concerning residential history, LAN, occupational exposure, and appliance use; spot measurements using an Emdex-2 meter, which provides more detail than the meters used in most studies; 24-hour personal monitoring, which requires maintenance of a diary; 6-day measurements in the most frequently used room in the house (other than the bedroom); 72-hour measurements in the bedroom; and wire coding.

Because this study uses subjects from a larger project, it can be done efficiently and can use a wealth of previously collected data on its participants, including data on known risk factors. In addition, selection bias is unlikely because wire coding does not require consent to participate in the study. Another strength of the study is its stable study population; the average length of stay in current residence was 22 years, and 76 percent of subjects occupied only one residence in the past 10 years. To date, researchers have collected data on about 200 cases and 200 controls and probably will complete data collection in September 1999.

LIGHT IN THE ENVIRONMENT
Daniel F. Kripke

Dr. Kripke presented his and other researchers' findings about light exposure and melatonin. Dr. Kripke's study of a randomly selected representative sample of San Diego adults age 40 to 64 resulted in a normal distribution of light exposures with a median exposure of about 300 lux over a 24 hour period (Kripke et al., 1994). In general, he estimated, most people spend 1 hour each day outside in bright light (about 5000 lux) and the rest of the day indoors with much dimmer light. There is a thousandfold range of illumination exposure between a person who spends all day inside in dim light and one who spends all day outside in bright light.

While it is clear that light can affect melatonin, it is rare for a person to be exposed before going to sleep at night or during the night to the level of light sufficient to suppress melatonin. To suppress melatonin 40 to 60 percent, one would need to be exposed to 500 to 1000 lux for 1 or 2 hours. In addition, some people are exposed to light so insufficient that their melatonin increases and causes depression, an illness called *seasonal affective disorder*. Depression during all times of year may be caused by inadequate light, Dr. Kripke said, and people may need to increase their exposure to light to maintain their health.

Next, Dr. Kripke explained evidence that melatonin's normal pattern—rising at night and peaking at midsleep—may change with age. A study supported by the National Institute on Aging found that peak levels for those age 18 to 40 almost always occurred between 1:30 and 6:00 a.m., but 48 percent of peak levels for those age 60 to 79 occurred outside the normal time range for young adults, sometimes in the middle of the afternoon (Kripke et al., 1998). A similar study supported by the National Heart, Lung, and Blood Institute found that melatonin peaked outside of the normal time range in 40 percent of older people (Kripke et al., 1998). For both studies, many people with abnormal peak times excreted normal amounts of melatonin. These and other findings suggest that melatonin levels in some older people cannot be suppressed by daylight or by controlled light sufficiently bright to suppress melatonin in younger people. Melatonin measurements for these older people, therefore, cannot be taken at night exclusively. More research in this area is needed.

In addition to changes that occur with age, there are individual differences in melatonin excretion levels (a 1000 percent range). Whatever effects EMF has on melatonin, EMF will not account for much of the variance when compared to the normal range among individuals. Although Dr. Kripke is still collecting data, to date he has found no relationship between total daily lighting and melatonin excretion, between LAN and total melatonin excretion or nighttime melatonin excretion, or between EMF and nighttime melatonin excretion.

In conclusion, he mentioned that 40 percent of the women in his study are taking antihypertensive medication, and 80 percent are taking aspirin or another nonsteroidal, anti-inflammatory drug, all of which reduce melatonin levels. These drug effects are more clear and probably more significant than reductions caused by EMF. Although EMF and melatonin may affect breast cancer, he was skeptical that EMF promoted cancer by suppressing melatonin.

WHEN TO STOP ASSESSING RISK AND START DEVELOPING PRUDENT AVOIDANCE MEASURES

Doreen Banks

Without much input from the public, several states are setting standards for EMF. This practice is problematic because the public is not involved in the process and because standards frequently are set at current levels of EMF, thereby legitimizing the status quo. On a worldwide scale, the International Radiation Protection Association established a "safe" guideline of 1,000 mG, a level

far exceeding the 2- to 3-mG exposure some researchers suggest may promote cancer. Once standards are established, it will be difficult to lower them without strong evidence linking EMF to breast cancer.

The appropriate government response, according to Ms. Banks, is to facilitate further research and communicate with citizens about these issues. A cost/benefit analysis of changes in the delivery of services—burying power lines, changing the shapes and dimensions of poles, and reconfiguring conductors—will help officials, the public, and utility companies make decisions about minimizing exposure.

Ms. Banks also recommended that people take action to reduce their exposure without waiting for more conclusive evidence. She recommended the following prudent avoidance measures:

- Utility companies should be required to inform homeowners about EMF.
- All homeowners should have the EMF tested in their homes and should move beds (if indicated), step away from major appliances during their operation, and discard old clock radios and electric blankets.
- Manufacturers of electric blankets and appliances should be required to indicate the EMF levels emitted from their products.
- When new homes are constructed or when existing homes are sold, utility companies should be required to measure the EMF in the home.
- Zoning laws should require a reasonable distance separating distribution lines and substations from senior and child care centers.
- State departments of health should measure the EMF in all schools, hospitals, parks, and senior centers that are close to distribution lines and substations, and they should track the amount of electricity produced by substations and carried by lines.
- The government should take a different approach to changing regulations that relate to health concerns. Specifically, government specialists should communicate better across agencies.

In closing, Ms. Banks said that the diagnosis of breast cancer is extremely difficult to accept when its cause may be EMF exposure, a risk that is relatively easy to reduce. People should be aware of the potential risks of EMF and how to minimize them.

PUBLIC PERSPECTIVE
Louis Slesin

First, Dr. Slesin described the public's rising concern about the potential risks of EMF exposure. In spite of the tremendous economic interest arguing against mitigating EMF and the lack of interest from national environmental, consumer, and labor groups, the public's response to polls and its frequent requests for government documents about EMF indicate that public concern is growing.

Dr. Slesin then focused on the state of the research. In only the last 10 years—when Dr. Stevens published the melatonin hypothesis (1987)—and with sparse resources, research in the cellular, animal, and epidemiologic domains has advanced greatly. Although data are preliminary and inconclusive, they are intriguing and may be strong enough to support the adoption of prudent avoidance measures. Scientists, however, need to conduct more research to reconcile discrepant findings and discover the truth about the effects of EMF. Currently, researchers can neither confirm nor refute that EMF causes or promotes cancer.
The research on EMF, therefore, is at an important juncture. Despite increasing public concern, escalating controversy surrounding EMF, and mounting provocative data, funding sources are slashing financial support. Even a brief suspension of the research will set it back several years, because research teams with expertise and equipment will disperse. Termination of the research will destroy opportunities to reduce the risks of breast cancer.

The role of the public, Dr. Slesin concluded, is to apply pressure to funding agencies and institutions to ensure that research continues.

ROUNDTABLE DISCUSSION: COMMENTS AND NEXT STEPS

The following action items were advocated by individuals. They do not reflect consensus among all participants, nor do they represent the policy of the NAPBC.

Research Comments

- **Maintain or increase funding to permit research to continue on the relationship between EMF and LAN and human breast cancer.** Due to national funding cuts within the U.S. DOE and elsewhere, research may not be able to continue without interruption beyond fiscal year 1998, and the groundwork that has been laid will be lost as research groups in this area disband. In addition to seeking funds from the traditional government sources, researchers should employ the following, more aggressive approaches to securing financial support: (1) develop solid, positive relationships with utility companies that may be willing to fund research not financed by the government; (2) collaborate with local advocacy groups that have lobbying power; and (3) garner public support for funding by presenting complex research issues in mainstream publications. Research traditionally has been oversimplified for the public. Given the opportunity to see all the complexities in the research, consumers may understand and support the need for additional funding.

- **Continue targeting the melatonin hypothesis in future research.** The hypothesis is credible in the EMF field, and its study is valuable because of melatonin's role in the development of breast cancer and its connection with the immune system. Specifically, continued occupational and other case-control studies are needed, as are prospective studies. Although current approaches to studying the melatonin hypothesis have yielded promising results and should continue, some new directions in melatonin and breast cancer research include:

  - The interaction between organophosphate pesticides, which cause visual system effects, and EMF exposure in animals and in occupationally exposed workers.

  - Hypersensitivity to electromagnetic fields.

  - The use of melatonin, either by itself or as an adjunct to tamoxifen treatment, in the clinical management of breast cancer.

  - The potential oncostatic effects of the anti-oxidant properties of melatonin.

  - The effects of EMF and LAN on daytime levels of melatonin.

  - The effects of nonsinusoidal wave forms, especially transients, on melatonin.

  - The influence of postdiagnosis EMF exposure on prognosis.

  - The method by which EMF acts on melatonin levels (possibly through the eye as LAN does).

  - DNA breaks as studied by Henry Lai, Research Associate Professor of Bioengineering at the University of Washington (Lai and Singh, 1997a, 1997b).

- **Increase collaboration among researchers.** Although findings in biological research have often triggered epidemiologic studies and vice versa, increased cross-fertilization in the fields of cellular, animal, and human research will consolidate and advance the body of evidence on breast cancer. Similarly, research on breast cancer should not be segmented from research on other kinds of cancer. Also, a more collaborative research structure would produce better data more economically. Currently, cost and feasibility issues confine the data that reasonably can be collected in small studies. Funding sources, however, could require research groups to develop collaborative teams to collect data on many potential environmental and biological factors and their interactions. Although a large, prospective, epidemiological study tracking many factors in women without breast cancer would be ideal, "add-ons" to existing research projects likewise can produce better

data for less money. Studies like the Women's High-Risk Breast Cancer Project at the Kansas University Medical Center (funded by NCI), which follows extremely high-risk women without breast cancer, would be a cost-effective and time-saving candidate for a research add-on that could integrate the additional measures of melatonin levels, LAN exposure, and other factors. In addition, studies in which a urine sample is collected to measure the melatonin metabolite also could measure the estrogen metabolite.

Public Statement Comments

Many participants recommended that the NAPBC issue a statement, primarily to inform the public about the potential risks of EMF exposure. Specifically, the statement should:

- Recommend a level of prudent avoidance commensurate with recent research developments.

- Comment on the potential level of harm associated with EMF. Possible comments, with varying levels of confidence in the effect of EMF on the development of breast cancer, include "EMF shows some cause for concern," "EMF affects the endocrine system in ways that cause concern," "EMF's association with certain cancers is clear," or "EMF is carcinogenic".

- Advocate increased research funding (see Research Comments).

- Highlight the discrepancy between Federal standards for permitted levels of EMF and the levels that animal research has indicated promote cancer.

- Recommend that an NAPBC member be designated to monitor and interact with the International Advisory Committee to the World Health Organization (WHO) for the International EMF Project, which is preparing to "harmonize [EMF] standards for all countries." Currently, WHO is conducting a 3-year EMF research program that ultimately may set a global EMF standard of 1000 mG, which will preempt national and state efforts to set a more reasonable standard.

- Repudiate the International Commission on Non-Ionizing Radiation Protection EMF standard of 1000 mG (5000 mG for workers). Although it would be premature to establish a standard labeled "safe," the statement could support a common sense approach like ALARA or prudent avoidance measures.

- Explain that ground currents, which are a violation of building codes, are a substantial source of EMF exposures in homes, workplaces, and schools, and recommend a law requiring the use of ground fault interrupters (like those found in bathrooms) in main circuits or in all circuits. Without increasing cost, replacing regular circuit breakers with

ground fault interrupters would prevent the use of electricity in the presence of a ground current, thereby ensuring the correction of current building code violations.

Additional Comments

Industry-Focused Comments

- Lobby for a Federal mandate requiring electrical products to display a label stating the EMF produced by the appliance or the distance from the appliance one must stand to be exposed to a field no higher than 2mG. *Consumer Reports* and consumer groups may be interested in supporting and publicizing this recommendation and may create a list of appliances to target.

- Encourage manufacturers to implement other methods of minimizing EMF, such as shielding appliances and developing low-field designs.

- Educate architects and builders about economical methods for reducing EMF levels in homes, schools, and workplaces.

- Motivate utility companies to support research and implement safety strategies by encouraging consumers to consider those factors when selecting a company.

Consumer-Focused Comments

- Publicize the potential risks of EMF exposure through media campaigns and the education and collaboration of consumer and advocacy groups.

- Initiate an ongoing public education program that will explain in understandable terms how people can characterize the EMF levels in their environment and mitigate them if necessary.

- Make reliable gauss meters available from local consumer and advocacy groups and at libraries so people periodically can measure EMF levels in their homes and workplaces. (Some utility companies also will take measurements.) Personal meters also can be made available on a limited basis. Consumer groups should select meters that have been evaluated for precision and reliability and should provide training on their use. (Several participants recommended FW Bell's Model 4080 meter and the Emdex Light personal or portable meter.

- Develop educational material providing a context for the measurements. Although such material could not indicate a distinct cutoff for what is a “safe” or “harmful” level, potential approaches for explaining measurements are (1) using an equity standard that would

explain average exposures (0.5 to 0.9 mG in homes, 1 to 2 mG in occupational environments) and (2) using a standard based on suggestive but inconclusive evidence. A potential standard could read, "cancer risk begins to increase after 1 mG in some studies. Between 1 and 2 mG, there is a doubling of risk; between 2 and 3 mG, tripling; between 3 and 4, quadrupling." Two booklets explaining measurement procedures and results are available through Carnegie Mellon University.

- Describe simple ways to mitigate exposure, including relocating beds away from EMF; not standing near operating appliances like microwaves, washing machines, and copiers; and repairing minor wiring problems.

- Develop educational materials that target specific labor and professional groups. Teachers, for example, have a high rate of breast cancer, and many of them regularly use overhead projectors, which produce 50- to 60-mG fields. Educational materials for teachers, therefore, can explain simple methods to decrease the exposure created by projectors and by other teaching aides that contribute to environments with high EMF levels. Other target groups include nurses, flight attendants, pilots, communications workers, radiologists, machine and computer operators, construction and railroad workers, electricians, interior designers (especially kitchen designers), architects, cancer survivor groups, environmental groups, Parents and Teachers Associations, Mothers and Others, and Nine to Five.

- Initiate school-based programs that target science, biology, and physics teachers. After the teachers get their students involved, parents will become engaged.

- Lobby for state-mandated EMF measurements in all schools and for adjustments to schools that exceed acceptable EMF levels.

- Publicize government-sponsored EMF hotlines:

  - National Institute on Environmental Health Sciences (NIEHS): 1-800-363-2383.
  - National Institute for Occupational Safety and Health (NIOSH): 1-800-356-4674.

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